National Park Service
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Monitoring Cave Entrance Communities and Cave Environments in the Klamath Network

2010 Pilot Study Results

ON THE COVER
Cave pseudoscorpion in Lava Beds National Monument.
Photograph by: Jean Krejca

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Abstract

In January and February of 2010, a pilot study was initiated for the Klamath Network monitoring protocol focused on Cave Entrance Communities and Cave Environments. During the pilot study, eight individual Standard Operating Procedures (SOPs), corresponding to eight monitoring parameters, were implemented in caves at Lava Beds National Monument (LABE) and Oregon Caves National Monument (ORCA). The objectives of this pilot study were to evaluate the operational feasibility of the SOPs for field sampling and to collect data from a representative subsample of caves and environments at LABE and ORCA using proposed methods.

Of the eight parameters proposed for monitoring, each was either measured during the pilot study or was evaluated based on past park monitoring or current procedures in place at the parks.

The pilot study determined that one of the parameters (dust and lint) should be discarded due to lack of effective monitoring methods. The seven remaining parameters can be monitored as part of the protocol, although several of the methods in the SOPs will need to be modified based on recommendations in this report.

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Introduction

The cave monitoring effort being implemented in this pilot study is a shared endeavor between the Klamath Network Inventory and Monitoring Program (KLMN), Lava Beds National Monument (LABE), and Oregon Caves National Monument (ORCA). LABE and ORCA are the two park units in the Network that contain significant cave resources. In 2004, the KLMN held a vital signs selection process, where cave entrance communities and cave environments were selected as two of the top 10 vital signs to monitor. Several scoping meetings with Network and park staff and cave experts from Zara Environmental were held in 2008; the outcome of these meetings was that specific cave parameters were selected to be monitored. The discussions involved evaluating cost, feasibility, ecological information obtained, and response to likely stressors to weight alternate parameters. Ultimately, eight cave parameters were selected for monitoring:

1. Cave Meteorology
2. Ice and Water Levels
3. Dust and Lint Accumulations
4. Human Visitation
5. Fern, Moss, and Lichen Coverage
6. Bat Populations
7. Scat Deposition
8. Cave Invertebrates

For each of these parameters, a draft standard operating procedure (SOP) was developed by Zara Environmental and submitted for comments and testing. As part of the protocol approval process, a pilot study was implemented to test the methods and analysis associated with this protocol. The primary objective of the pilot study was to implement the SOPs to evaluate operational feasibility of the field methods, appropriateness of equipment, and to gain a better understanding of the type and variability of the data obtained. Furthermore, the pilot study was designed to provide an estimate of the time expenditure that will be required to implement each SOP.

The monitoring protocol will be implemented at ORCA in two caves and at LABE in 31 caves (Krejca and Myers 2010). At ORCA, Oregon Cave and Blind Leads Cave will be monitored. Oregon Cave is a show cave containing a developed tour route, though much of the cave remains wild and undeveloped. Monitoring sites will sample both on-trail and off-trail areas. Blind Leads Cave is a small, undeveloped cave located along a nature trail in the Monument. The cave is signed and receives a moderate amount of visitation. At LABE, 31 caves containing a diverse assemblage of resources will be monitored. Of these 31 caves, 11 are visitor use caves that contain varying degrees of signage and infrastructure. The remaining 20 caves are undeveloped caves that receive little to no visitation. Also within the set of 31 caves are eight caves known to contain hibernating bat populations and six caves known to contain ice resources.

Methods

Site Selection – Lava Beds National Monument

Pilot study implementation was conducted in several LABE caves according to the parameter being monitored. This section details the placement of HOBO dataloggers to correspond with entrance, middle, and deep cave zones. These three zones also serve as the locations for conducting invertebrate and scat monitoring; therefore, site selection for monitoring will be generally based on cave climate monitoring sites. In addition, bat monitoring was conducted in over 20 caves and ice monitoring was conducted in seven caves. Fern, moss, and lichen (entrance vegetation) monitoring will be conducted at all cave entrances in the monitoring sample.

Dataloggers were placed in three LABE caves according to the methods outlined in SOP #1. Four loggers each were designated for Caldwell Cave, Wishbone Cave, and Catacombs Cave. For each cave, a logger was placed in the entrance, middle, and deep zones, as well as a surface logger near the entrance. The loggers designated for the selected caves were named and placed as follows:

<u>Caldwell Cave</u>
CALD_ent_2418982
CALD_mid_2418986
CALD_deep_2418994
CALD_out_2418983

Caldwell Cave (Figure 1) lends itself well to the idea of placing loggers in distinct cave zones corresponding to entrance, middle, and deep zones. Caldwell Cave has a distinct lower level that is noticeably colder and even contains ice, so this area was chosen for the deep logger. The entrance location was somewhat arbitrary, as Caldwell has six entrances (plus a skylight). The main entrance that is typically used to access the cave was chosen, and the logger was placed in an alcove within the extent of the twilight zone. The middle logger was placed in a passage that parallels the passage with both the entrance and deep loggers, and this logger was suspended fully in a dark zone. The surface logger was hung within a tree near the lip of the main entrance.

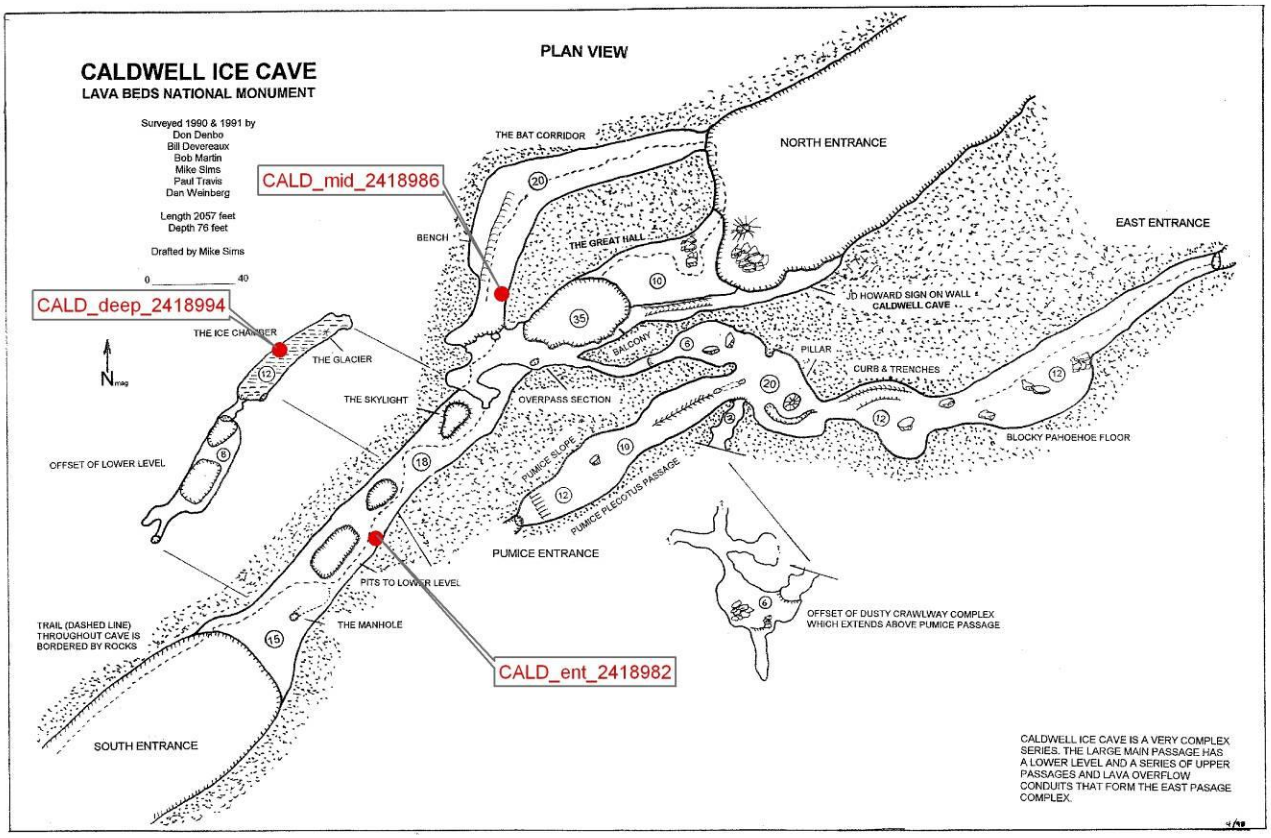

Figure 1. HOBO datalogger sites in Caldwell Cave.

<u>Wishbone Cave</u>
WISH_ent_2418993
WISH_mid_2418995
WISH_deep_2418987
WISH_out_2418996

Wishbone Cave (Figure 2) again presented a choice as to which entrance to select for placing the entrance logger. This choice was rather arbitrary, as none of the three entrances would necessarily be considered the “main” entrance. Based on the entrance selection, the middle logger was placed within the dark zone of one of the passages that branches off from the entrance. The deep logger was placed in a terminal passage that was presumed to be the furthest location from the entrance. The surface logger was again hung within a tree near the lip of the entrance containing the entrance logger.

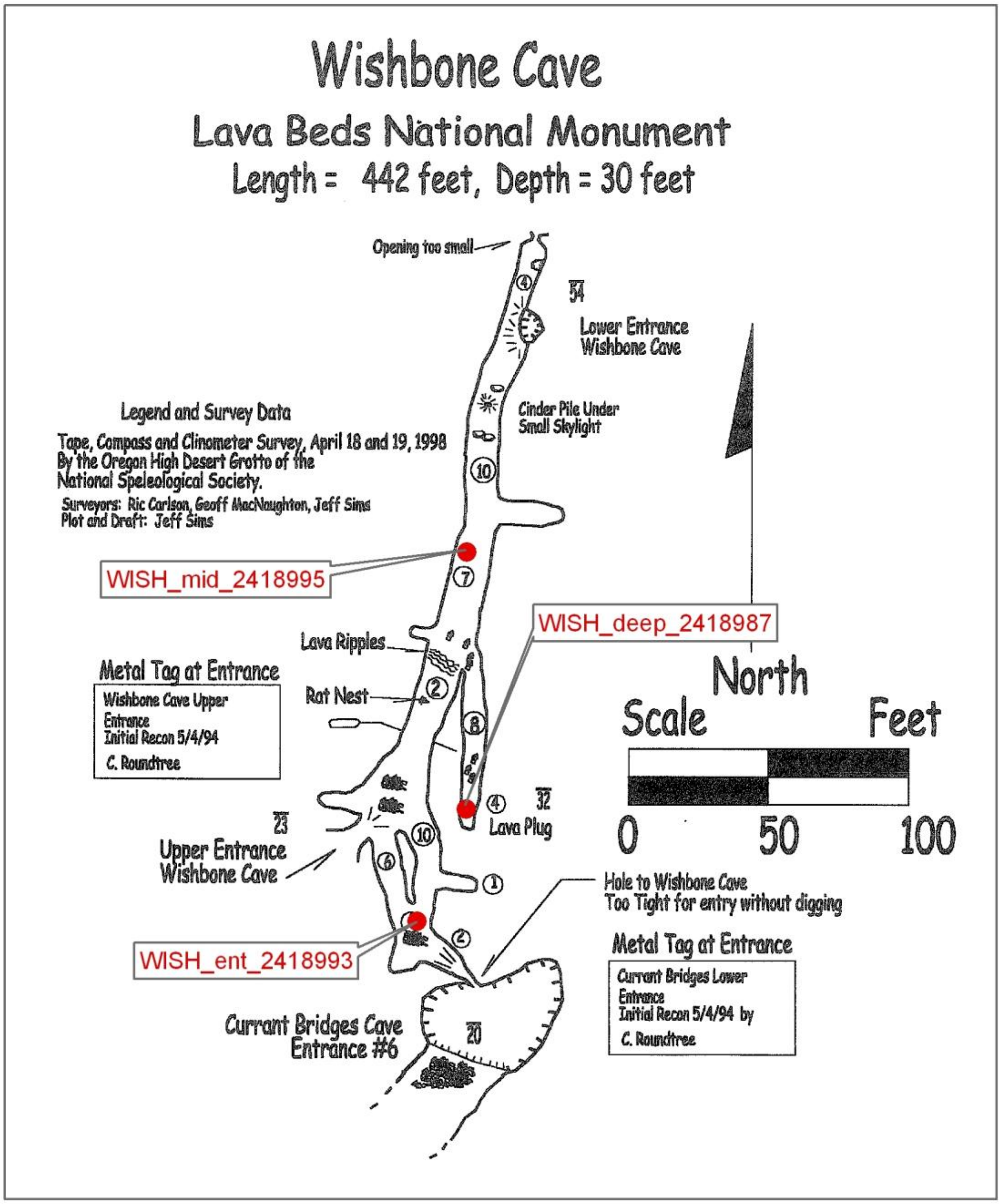

Figure 2. HOBO datalogger sites in Wishbone Cave.

<u>Catacombs Cave</u>
CATA_ent_2418991
CATA_mid_2418990
CATA_deep_2418980
CATA_out_2418988

Catacombs Cave (Figure 3) is an extensive cave with a single entrance. Scat and invertebrate monitoring had been previously conducted in Catacombs Cave for the pilot study, so the middle and deep logger locations were chosen to correspond with the zones that had been set for that monitoring. Though Catacombs does not contain a lower level as Caldwell Cave does, we judged that the extensive length of the cave and its relatively linear nature justifies the distinction between middle and deep climate zones.

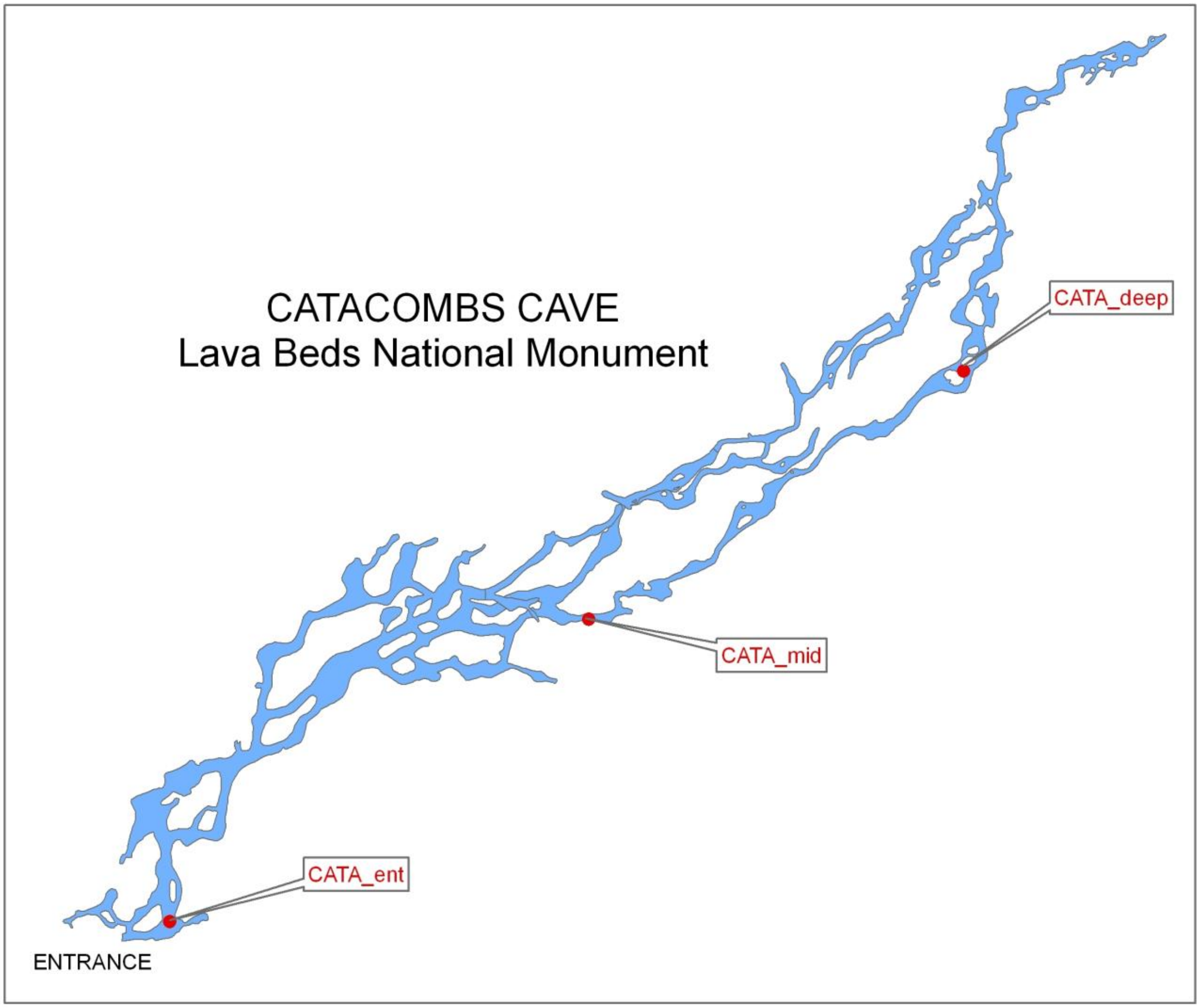

Figure 3. Datalogger sites in Catacombs Cave.

Site Selection – Oregon Caves National Monument

Monitoring at ORCA will generally occur at sites corresponding to placement of HOBO dataloggers. Other parameters, though, may be site-specific, such as bat surveys and seasonal pool monitoring.

Dataloggers designated for Oregon Cave (Figure 4) were named according to the two-letter convention that has been used for several years at ORCA and that is called for in SOP #1. The code refers to place names within a single cave so that two letters are sufficient to establish unique and intuitive logger names. Site selection was primarily based on existing locations, with additional logger sites chosen to achieve a spatially balanced array of sites covering the entire cave. Twelve new HOBO Pro v2 dataloggers were placed in Oregon Cave (Table 1).

Table 1. New HOBO loggers placed in Oregon Cave.

Location	Code	Logger name
outside Main Entrance*	OM	OM_9697421
Belly of the Whale	BW	BW_9697422
Jack's Pass*	JP	JP_9697427
King & Queen's Throne Room*	KQ	KQ_9697420
Miller's Chapel	MC	MC_9699574
Jules Verne Well*	JV	JV_9699568
Wedged Rock*	WR	WR_9699572
Sand Room*	SA	SA_9699571
Bear Bones	BB	BB_9699569
Clay Pocket	CP	CP_9699573
Exit Tunnel*	ET	ET_9699570
outside Exit Tunnel*	OT	OT_9697428

Eight dataloggers were placed in new locations (indicated by *) that have never previously had a logger, including two outside surface locations that correspond to two Oregon Cave entrances. Four additional loggers were used in existing sites to replace old loggers that have either been lost or have stopped working. Eight additional sites in Oregon Cave contain older, "hockey puck" style loggers that have not been replaced (Table 2).

Table 2. Old HOBO dataloggers in Oregon Cave that have not yet been replaced.

Location	Code
Watson's Grotto	WG
Beehive Room floor	BRF
Beehive Room ceiling	BRC
Wind Tunnel	WT
Ghost Room floor	GRF
Ghost Room ceiling	GRC
Paradise Lost	PL
South Room	SR

Also, the current monitoring plan calls for dataloggers within the twilight zone of all Oregon Cave entrances, so this will require placement of another three loggers (Table 3).

Table 3. New sites where HOBO loggers will be placed in Oregon Cave.

Location	Code
Main Entrance	ME
110 Entrance	110
Icebox Entrance	IE

Eleven new HOBO Pro v2 dataloggers will be required to fulfill the climate monitoring SOP at ORCA. Adding new loggers to these sites will streamline download procedures and allow for consistency in data collection and management.

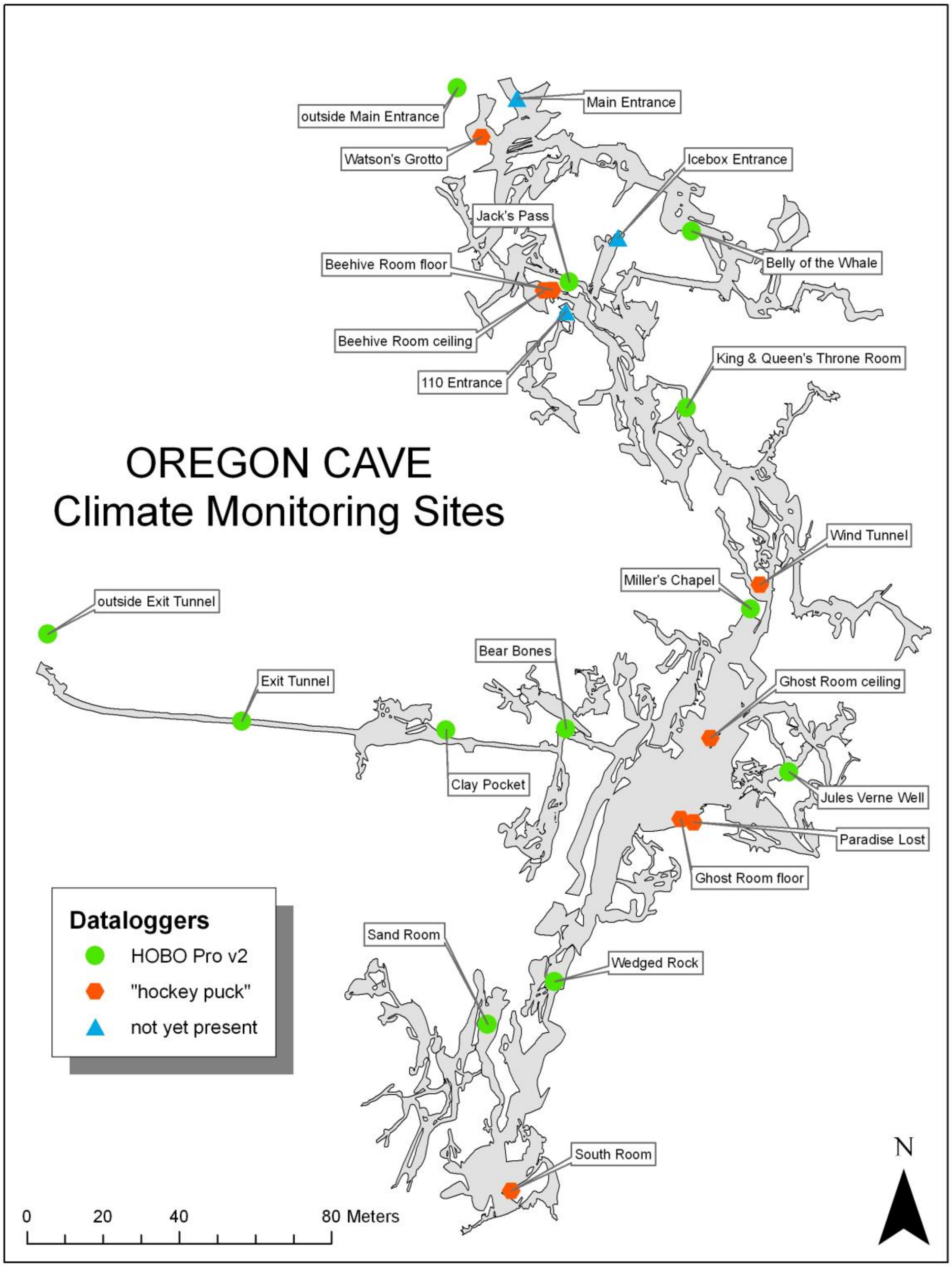

Figure 4. HOBO datalogger sites in Oregon Cave.

Four new dataloggers were also assigned to Blind Leads Cave (Figure 5), a small cave within the Monument. The locations for these dataloggers (Table 4) were chosen to correspond to entrance, middle, and deep cave zones as well as a surface location.

Table 4. New HOBO loggers placed in Blind Leads Cave.

Location	Logger name
tree above entrance series	BL_out_9697426
alcove inside upper entrance	BL_ent_9697425
constriction at end of lower level	BL_mid_9697423
far end of upper level crawl	BL_deep_9697424

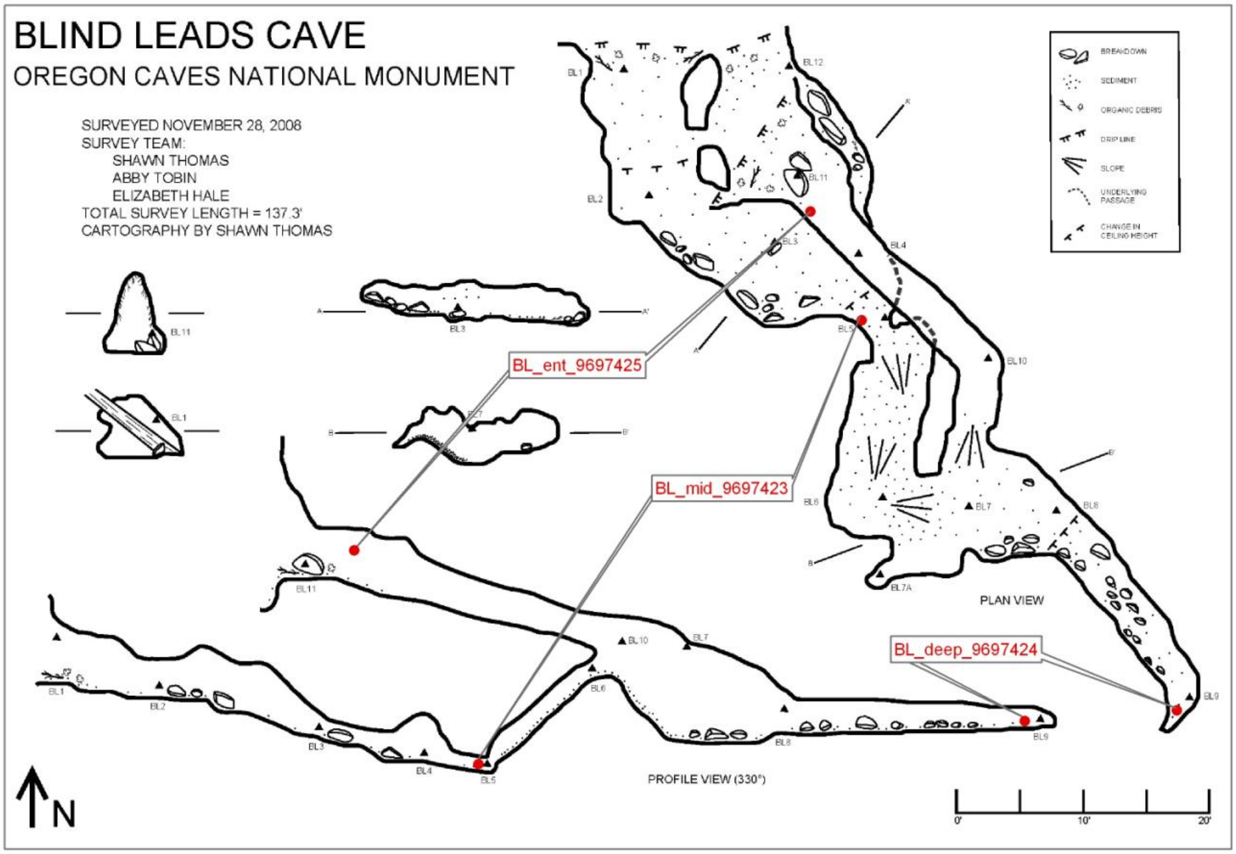

Figure 5. HOBO datalogger sites in Blind Leads Cave.

Results

SOP 1: Climate Monitoring

Pilot study implementation of climate monitoring consisted of placing HOBO Pro v2 dataloggers in Caldwell Cave, Wishbone Cave, and Catacombs Cave at LABE and in Oregon Cave and Blind Leads Cave at ORCA. Climate data were collected over a period ranging from 1 to 4 weeks.

According to the SOP, the serial number of each data logger was incorporated into the naming convention for the logger and data files. For loggers in Oregon Cave, a two-letter code was used, as specified in the SOP; however, for Blind Leads Cave and all LABE caves, a portion of the name was modified by using a four-letter code to designate the specific cave. Adopting a four-letter code allows the use of standardized naming already followed by LABE, in which the four-letter code is comprised of the first four letters of a cave with a one-word name or the first two letters of each word for a cave with a two-word name. Furthermore, this system eliminates the scenario of having to elect a non-intuitive two-letter code for a cave that shares a similar name with another cave on the monitoring list.

The HOBO Pro v2 dataloggers were extremely easy to use, as was the HOBOware software that is used to configure the loggers and download data from the shuttle. The loggers and shuttle were reliable, with no communication problems or data loss occurring during the pilot study. All climate data recorded during the pilot study were submitted for power analysis.

SOP 2: Ice/Water Levels

Lava Beds National Monument

At the meeting in Ashland on December 1, 2009, it was decided that the methods for ice monitoring should be expanded to include more data points, thereby better defining the extent of ice resources. Measuring to only one point on an ice floor, as written in the current methods, may not adequately detect changes in ice volume or differential rates of growth or melting across an ice floor. Furthermore, the ice monitoring method written in the SOP is more complex than necessary and prone to error. This method, which involves surveying from a fixed point to the closest extent of ice, requires measuring distance, azimuth, and inclination. The current method in use at LABE requires measuring only the vertical distance from a fixed point to the ice floor, thus acquiring the same information (change in ice thickness) through a much simpler and less error-prone technique.

A perimeter survey was discussed as a means of acquiring a better “picture” of overall changes in ice extent. For this purpose, a TruPulse laser rangefinder was tested on the ice floors in Caldwell Cave and Cox Ice Cave. The TruPulse captures distance, azimuth, and inclination simultaneously. Though the unit was easy to use and allowed a quick perimeter survey, the distance accuracy is too coarse to conduct ice monitoring. Distance can only be displayed to the nearest 0.5 feet with an accuracy of ±1 foot, which is insufficient for detecting changes in ice levels.

Possible monitoring method: Using a tripod with a panoramic disc engraved with a 360° scale would allow for measurement to points at fixed intervals around the perimeter of an ice floor. The tripod could be placed roughly in the center of the floor; surveying to a control point on a cave wall would establish the center of the survey. Using a fixed control point on a cave wall to locate the survey center eliminates the need to create a fixed point at which the instrument needs to always be located, which would be difficult on an ice floor that fluctuates through time. Based on the azimuth measured from the survey center to the control point on the cave wall, all other azimuth values could be determined from the panoramic disc on the tripod. From the survey center, a laser rangefinder could be used to collect distance and inclination data to points along the edge of the ice floor. The Leica Disto D8 is capable of collecting distance data with an accuracy of ±1.0 mm and can measure slope at any inclination. This instrument also has Bluetooth wireless technology, so data could be transferred and stored on a digital device, making for accurate and rapid data collection. The number of survey points recorded may depend on the size and shape of the ice floor, but given the efficiency possible with this method, a minimum of 60 points should be established. This corresponds to taking measurements at an interval of every 6°. For ice floors where greater resolution is desired, an interval of every 3° would produce a survey with 120 points. The points could then be plotted in Compass or a similar software program to generate a lineplot. By "connecting the dots," the perimeter of the ice floor could be graphically defined and a surface area calculated. Below (Figure 6) is an example of a line plot produced with this type of data, though in this case data were collected for only 10 points, which are not enough to fully characterize the shape of the perimeter.

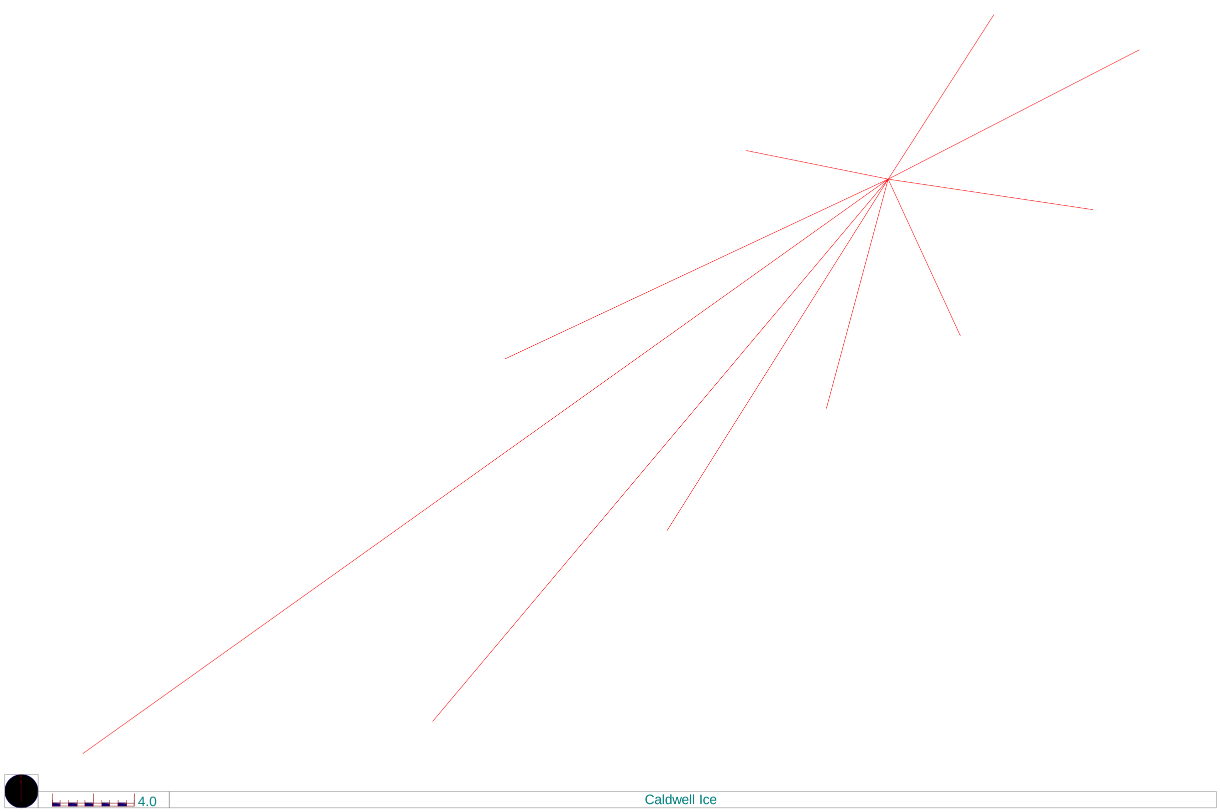

Figure 6. Extent of Caldwell Cave ice floor illustrated with perimeter survey data.

Current monitoring method: It may be of value to continue current monitoring methods in conjunction with the methods described above. Currently, ice floors are monitored by measuring the vertical distance from a fixed screw on a cave wall to the ice floor. The data generated from this method illustrate melt or growth by showing whether ice floors are lower or higher over time relative to the screw. Essentially, the change in thickness is being measured, despite the actual thickness of the ice being unknown. Though this information could also be extrapolated from data acquired with the perimeter survey method, a single direct distance measurement, as in the current method, allows for rapid assessment of changes in ice floor thickness.

Quantitative assessment: Using the methods described above would allow for quantitative analysis of changes in ice levels. The perimeter survey method could be used to calculate the surface area of ice floors, while the current monitoring method is used to calculate changes in ice thickness. Together, these methods could be used to estimate changes in volume. For example, on an ice floor where melting has occurred, multiplying the change in thickness by the current surface area would produce a minimum volume loss estimate, assuming that the current surface area is smaller than the previous surface area. This would typically be the case, as the surface area of an ice floor is influenced by cave topography and should generally increase with growth and decrease with melting. More complex analysis could be attempted to generate a better calculation for change in ice volume.

Oregon Caves National Monument

The methods for monitoring seasonal pools at ORCA have been in practice since winter 2008-09. Currently, depth gauges are located in a few pools throughout the cave and readings are taken at intervals ranging from weekly to monthly. Additional pools have been identified for inclusion in future monitoring efforts. Monitoring consists of reading the water depth from a graduated gauge in the pool and recording the depth to the nearest half centimeter. Monitoring of all pools can be accomplished in 1-2 hours, as the pools in the current selection are all located near the main tour route.

Sampling interval: The frequency of sampling at ORCA will need to be increased from what is currently written in the SOP. For ice monitoring, sampling twice per year during the winter and summer will provide satisfactory resolution for detecting seasonal changes. For seasonal pools, though, which fluctuate rapidly, sampling needs to occur at least monthly, and perhaps more often during the winter season. The seasonal pools in Oregon Cave tend to be completely dry throughout the summer and into the fall. The pools rapidly begin to fill in fall or early winter and then continuously fluctuate through the spring, until infiltration rates slow enough for evaporation to cause the pools to dry. Sampling only twice per year, once in winter and once in summer, poses the risk of missing the timeframe during which pools are most active; this timeframe is likely to vary from year to year depending on the timing of precipitation events. If only long-term trends are desired, as opposed to seasonal fluctuations in pool levels, then perhaps the level of maximum extent recorded in a year can be used for analysis.

SOP 3: Dust and Lint Monitoring

Pilot study implementation of dust and lint monitoring was conducted at LABE in Catacombs Cave. A transect of three petri dishes was labeled and placed in each of the three cave zones (entrance, middle, deep), making for a total of nine dishes in Catacombs Cave. The dishes were left in place for approximately 2 weeks before being checked. Upon inspection, almost all of the dishes were found to be completely covered with condensation (Figure 7). The only exceptions were the dishes in the entrance zone, which were partially but not completely covered with condensation. The presence of condensation rendered this monitoring method ineffective; this was among the reasons for rejecting dust and lint accumulation as one of the monitoring parameters in this protocol. Further details are included in the Discussion section.

Figure 7. Dust/lint monitoring dish covered in condensation after placement in Catacombs Cave.

SOP 4: Visitation Monitoring

No direct action was taken during the pilot study on visitation monitoring, as the methods outlined in the SOP have already been occurring at both LABE and ORCA.

Lava Beds National Monument

With initiation of the approved monitoring plan, LABE will expand its visitation monitoring by adding infrared trail counters to visitor use caves that are part of the monitoring sample and by adding cave registers to backcountry caves in the sample.

Oregon Caves National Monument

With initiation of the approved monitoring plan, ORCA will continue to monitor visitation in Oregon Cave by ticket sales records for visitors and a cave register for staff. ORCA will also add a cave register to Blind Leads Cave for monitoring visitation in this small cave.

SOP 5: Fern, Moss, and Lichen Monitoring

No action was taken during the pilot study on this SOP, as it is still being reviewed and modified by Klamath Network staff.

Recent discussion on potential methods for fern, moss, and lichen monitoring has trended towards collecting point data along transects parallel and/or perpendicular to cave entrances. This method would likely still be supplemented with photo monitoring, as described in the current version of this SOP.

SOP 6: Bat Surveys

The bat monitoring methods have received the most attention during the pilot study. Though a resolution has not yet been reached as to exactly how bat monitoring will proceed under this SOP, many important points have been discussed. This has largely resulted from recent collaboration between LABE resource staff and Ted Weller of the Forest Service Redwood Sciences Laboratory. Ted recently assisted with winter bat monitoring efforts at LABE and is currently in the process of reviewing all past bat monitoring efforts at LABE to help design a new database and make suggestions for future monitoring efforts. Preliminary discussions with Ted have introduced the possibility that winter monitoring of hibernacula sites may be the most critical, and in fact the only truly consistent, means of monitoring long-term population trends of the Townsend's Big-eared bat, *Corynorhinus townsendii*. Further discussion has centered on potential sampling designs and determining the number of caves that need to be monitored.

One of the most important questions needing resolution is how bat monitoring will relate to the remainder of the cave monitoring SOPs. Properly conducting bat monitoring with the purpose of collecting annual population estimates will require visiting a specific set of LABE caves on an annual basis to capture the majority of the known population. These caves cannot be randomly selected; instead, they must comprise the known significant hibernacula sites. It will not be possible to implement the full monitoring protocol in all of the hibernacula sites, as budget limitations constrain bat monitoring to a set of no more than about 20 caves. Making multiple annual visits to all of these caves, some of which are remote and require significant travel times, will not be possible. Instead, a subset of hibernacula sites, perhaps 5-10, should be selected for inclusion in the monitoring program. A subset of this size would be reasonable for implementation of all SOPs, though it must be understood that data from the additional hibernacula sites would need to be considered when conducting analysis on bat populations in the Monument.

Bat monitoring at ORCA takes place in conjunction with *Critter Surveys*, which have been conducted weekly to monthly, depending on season, since 2005. Bats are occasionally observed during the summer season, though encounters tend to be infrequent and centered near cave entrances. During the winter season, Townsend's Big-eared bats are known to hibernate in specific sections of Oregon Cave. Additional hibernating bats are occasionally seen at other sites, but no significant populations exist outside of Oregon Cave. The hibernating population has been monitored, with counts occurring several times throughout the winter season during recent years. Monthly counts have revealed patterns of dispersal that would otherwise not be known from a single annual count. These colony's movements may be entirely natural or may be influenced by disturbance, such as the ongoing maintenance projects and resource activities in Oregon Cave.

In Oregon Cave, winter hibernacula counts should be used as the primary bat survey method. The one decision that needs to be made is whether winter hibernacula counts should be conducted monthly, per the procedures of recent years, or annually, as written in the current SOP and as practiced at LABE.

- Monthly counts would be advantageous for maintaining the minimum sampling interval used from 2005 – present. Also, monthly counts would allow for documenting movement of the colony.
- Annual counts would lessen the chances of causing disturbance, though dispersal behavior documented in recent years would not be observed.

This SOP, as written, does not explicitly refer to a single species, though monitoring procedures in the SOP are most applicable at LABE and ORCA to *Corynorhinus* populations. Monitoring of other bat species at LABE or ORCA would not necessarily follow the same procedures as those in this SOP, as the sizes and behavior of colonies of different species would require monitoring procedures specific to that species.

Bat surveys were conducted in over 20 LABE caves during the pilot study. The bat monitoring form (Figure 8) was slightly redesigned to reflect updated methods. The following points are in reference to conducting in-cave counts and are observations and recommendations resulting from pilot study implementation:

1. Using a maximum of two surveyors is usually appropriate, though there are some exceptions. In a few of the hibernacula sites at LABE, large passage sizes make it advantageous to include a third surveyor, which allows the entire cave to be searched in less time and thereby minimizes disturbance. At ORCA, counts are typically conducted by a single surveyor.
2. Having each surveyor independently count all zones is not desirable, as this substantially increases the amount of time spent in the cave and increases interaction with bats. Counting clusters and identifying the species often requires a surveyor to approach fairly close to the bats. If each surveyor is required to do this, the chances of causing disturbance would be significantly increased.
3. Surveyors working together to identify bats and conduct counts has been a successful approach in LABE caves. The nature of the cave being surveyed dictates the strategy used to conduct the count:
    a. In small caves or zones, duties are often split between spotting, identifying, counting, and recording data. Experience has demonstrated that two surveyors coordinating their efforts is a strategy that allows for high detection rates, as both surveyors are simultaneously searching for bats and communicating each bat or cluster that is spotted.
    b. In large caves or zones, surveyors conduct counts independently in various sections of the cave or zone. Though this method does not allow for communication or verification of counts, it does expedite the survey and contributes to less overall time being spent in the cave, thereby minimizing disturbance.
    c. The methods used for each particular cave could be detailed on the field form that contains the zone designations to ensure that the procedures used are standardized and consistent from year to year.
4. Photographing bat clusters is not recommended due to the potential for disturbance.

5. It is not practical to record air and ceiling temperatures for every bat cluster counted. A maximum number of temperature measurements should be established; for example, recording temperature for a maximum of three clusters per zone would be reasonable.
6. When measuring air temperature below bats, there needs to be a way to ensure that the thermometer has had appropriate time to adjust to the ambient cave temperature and also that the thermometer is not influenced by body heat generated by surveyors. The thermometer used during the pilot study took a considerable time to acclimate, so the first air temperatures recorded were probably not accurate.
7. The laser thermometer works well for recording the ceiling temperature adjacent to bats, but recording three separate measurements does not seem necessary. During the pilot study, the three readings from the laser thermometer were almost always identical and the maximum discrepancy between readings was 0.1° F. It would be more appropriate to take three readings as a means of verifying the accuracy and then recording the most consistent reading.

Bat surveys: in-cave hibernacula counts

Cave: ______________________________ Date: __________________

Observers: ____

Remarks:

____

	Zone:	Zone:	Zone:	Zone:	Zone:
Start time:					
Stop time:					
Corynorhinus townsendii Record each bat or cluster count separately. Ex: 1,2,1,1,7,4,2,1,1,3					
Undetermined bat species					
Myotis spp.					
Other species (list below):					

	cluster 1	cluster 2	cluster 3	cluster 1	cluster 2	cluster 3	cluster 1	cluster 2	cluster 3	cluster 1	cluster 2	cluster 3	cluster 1	cluster 2	cluster 3
Ceiling temperature reading (°C)															
Air temperature reading below bats (°C)															

Figure 8. Bat Monitoring form.

SOP 7: Scat Monitoring

Scat monitoring was conducted in Catacombs at LABE and in Oregon Cave at ORCA and was implemented simultaneously with invertebrate surveys. Scat monitoring proved to be simple and efficient when using the newly created rodent scat count categories. It took little time to determine which count category (<10, 10 – 100, or >100) characterized a zone. The scat monitoring data form was filled out after completing a timed area search for invertebrates. Surveyors were told to keep a mental note of the amount and types of scat observed while performing the invertebrate survey. After recording invertebrate data, surveyors were asked approximately how many rodent scats were observed. The cumulative total of all surveyors was used to determine the appropriate count category. In addition, surveyors were asked what other kinds of scat were observed and if any other visible organics were observed. Dead invertebrates, such as spiders and millipedes, were the only sources of nutrient inflow noted at LABE during the pilot study, but at ORCA the presence of lint and plant remains was also recorded. For future monitoring, scat counts will need to be conducted separately (though on the same visit) from invertebrate surveys, as bait stations will be used instead of area searches.

The following points summarize changes made to the data form (Figure 10) and additional recommendations resulting from pilot study implementation:

1. The name of the data form was changed to *Visible Organics Monitoring* to reflect the inclusion of other categories of nutrient inflow, such as dead animals, plant remains, trash, and lint.
2. Instead of requiring a raw count of rodent scat, the new data form now includes three rodent scat count categories: <10, 10 – 100, and >100. It was decided to use these categories instead of a raw count because counting individual scats would be impractical in many cases. In cave areas with high concentrations of scat, it would be impossible to count each individual scat, especially when scat is situated in a thick, layered pile.
3. A category was added to indicate the proportion of scat that is covered with mold or fungus. This provides an indication of how fresh the scat may be, as most molds and fungi are only found growing on relatively recent scat (less than one year old?). Indicating the proportion of affected scat in broad categories ($<{}^{1}/_{3}$, ${}^{1}/_{3} – {}^{2}/_{3}$, $>{}^{2}/_{3}$) makes the determination relatively simple while still adding valuable data.
4. Several parameters were added as checkboxes to indicate their presence. Adding commonly seen organics to the data form promotes consistent recording of their presence and makes the recording process more efficient than having to write comments under the *Notes* section.
    a. During the scat monitoring conducted at LABE in Catacombs Cave, pika scat was observed in Zone 1, which encompasses the cave entrance. Pikas are a species of particular concern and are known to use cave environments at LABE.
    b. Dead invertebrates were commonly seen during scat monitoring at both LABE and ORCA.
    c. Human-introduced sources of nutrient inflow were added to the data form. Lint is known to be a possible nutrient source for invertebrates and was found in abundance at one of the zones in Oregon Cave where scat monitoring occurred. Trash and human waste are both commonly seen in LABE caves, though less so at ORCA.

    d. Vertebrate remains were added, as dead woodrats or other vertebrates are occasionally found in caves and their presence is a significant nutrient source.
    e. Plant remains are common within entrance areas of caves and contribute to nutrient inflow.
5. Changing the SOP name to *Visible Organics Monitoring* would better reflect the goal of monitoring all forms of nutrient inflow, as opposed to just scat.
6. A “photo key” should be created to aid surveyors in identifying scat types. The key should include high-quality photos captured with a macro lens. A single key would be sufficient for both parks, as there should not be any significant visual difference between scat in the two locations, though some scat types may be site specific (e.g., pika scat at LABE). The key could be created through a collaborative effort between LABE and ORCA staff.

Visible Organics Monitoring

Cave: ____________________ Date: __________ Observers: ___________________

Zone: ________ Start Time: ________ Stop Time: ________

# Rodent Scats:	< 10	10 – 100	> 100
Proportion covered by Mold/Fungus:	< 1/3	1/3 – 2/3	> 2/3

Presence of:

- ☐ Bat Guano
- ☐ Pika Scat
- ☐ Owl Pellet
- ☐ Other Bird Waste
- ☐ Bird Nest
- ☐ Rodent Nest/Midden
- ☐ Dead Invertebrates
- ☐ Vertebrate Remains
- ☐ Plant Remains
- ☐ Lint
- ☐ Trash
- ☐ Human Waste

Notes: ____

Zone: ________ Start Time: ________ Stop Time: ________

# Rodent Scats:	< 10	10 – 100	> 100
Proportion covered by Mold/Fungus:	< 1/3	1/3 – 2/3	> 2/3

Presence of:

- ☐ Bat Guano
- ☐ Pika Scat
- ☐ Owl Pellet
- ☐ Other Bird Waste
- ☐ Bird Nest
- ☐ Rodent Nest/Midden
- ☐ Dead Invertebrates
- ☐ Vertebrate Remains
- ☐ Plant Remains
- ☐ Lint
- ☐ Trash
- ☐ Human Waste

*Notes:*____

Zone: ________ Start Time: ________ Stop Time: ________

# Rodent Scats:	< 10	10 – 100	> 100
Proportion covered by Mold/Fungus:	< 1/3	1/3 – 2/3	> 2/3

Presence of:

- ☐ Bat Guano
- ☐ Pika Scat
- ☐ Owl Pellet
- ☐ Other Bird Waste
- ☐ Bird Nest
- ☐ Rodent Nest/Midden
- ☐ Dead Invertebrates
- ☐ Vertebrate Remains
- ☐ Plant Remains
- ☐ Lint
- ☐ Trash
- ☐ Human Waste

*Notes:*____

Figure 9. Visible Organics Monitoring form.

SOP 8: Karst Invertebrate Surveys

Invertebrate surveys were conducted in Catacombs Cave at LABE and in Oregon Cave at ORCA. During the pilot study, only area searches were conducted, as bait stations had been tentatively removed from the monitoring protocol. With the decision to use bait stations instead of area searches, some of the following points are no longer relevant to this monitoring protocol.

The following are observations and recommendations resulting from pilot study implementation:

1. The title of the SOP should be changed to *Cave Invertebrate Surveys* to properly characterize all sites where this SOP will be implemented (LABE contains caves but not karst).
2. A photo key will be extremely valuable in aiding surveyors in correctly identifying invertebrates, by serving as a high-quality visual reference. This key should correspond to the species lists developed for the caves being monitored and separate keys for LABE and ORCA may be necessary.
3. There is currently no guidance in the SOP as to the size of zones. While it is not critical for all zones to be the same size, it is important that zones be sized appropriately to accommodate searching of the entire zone during the allotted search time. During the pilot study, the first zone that was surveyed was found to be far too large to be searched in 20 minutes. About half of the zone was covered in this amount of time, and the zone was estimated to be about 700 square feet. In contrast, the first zone that was set in Oregon Cave was about 300 square feet, and 20 minutes was appropriate to search this area. Based on this experience, it seems that setting a range of sizes for zones would be appropriate to ensure that the variable zone sizes are compatible with the fixed search time. A lower size limit of 300 square feet and an upper limit of 500 square feet is recommended.
4. In the current methodology, the quadrat data seems to merely be supplementing the zone data, though they are probably repetitious in many cases. The data collected from the quadrats seems to be of questionable utility considering that the quadrat locations are not recoverable and no other data are associated with the quadrat. In other words, what are we learning from the quadrats that is not already encompassed by the timed area search? Is the main purpose of the quadrat to do a more thorough search to ensure that every organism is seen, whereas animals are more likely to be missed during the timed area search? It would be helpful if the SOP included more explanation on *why* this is being done in addition to *how*.
    a. For quadrat data to be more meaningful, it would be easy to include substrate data by adding a list of substrate types to the datasheet and circling the appropriate one for each quadrat.
    b. In this SOP, quadrats are placed haphazardly; therefore, they share the same spatial resolution as that for the entire zone. In similar SOPs used by other parks, quadrats are placed in recoverable locations that are the same from year to year, thereby adding spatial information to data. What are the advantages of using haphazard quadrats as opposed to fixed locations?
    c. The SOP specifically calls for quadrats to be placed on the floor. What about walls, ledges, and ceilings?
5. Are 10 quadrats necessary, especially if zone size is restricted, as suggested above? During field testing, 10 quadrats felt excessive in even the largest zones used because the

10 quadrats had to be placed quite close to each other. Again, some explanation as to *why* this number of quadrats is needed would be helpful in understanding the methods.

6. The use of a sling psychrometer to measure relative humidity (RH) by capturing dry bulb and wet bulb temperatures seems unnecessary, considering that each zone in which invertebrate surveys are conducted will already have a HOBO datalogger in place to record temperature and RH. Furthermore, the instrument itself can be cumbersome to use in the cave environment and presents a hazard considering the possibility that a thermometer could shatter, causing fluid leaks and broken glass. The one advantage of using a sling psychrometer in addition to a datalogger is that the RH recorded by the psychrometer may be more accurate than the data obtained from the logger. If it is decided to continue the use of this instrument as part of this SOP, then a higher quality model should be purchased. Models commonly used by NPS Fire divisions are sturdier and much easier to operate and read.
7. What is the purpose of recording barometric pressure as part of this SOP? This should be explained in the SOP. It would be more efficient to record barometric pressure data on the zone search data form, as opposed to having a separate form to record it on. If the measuring of dry bulb/wet bulb temperatures is abandoned, then it would be very simple to add a space for barometric pressure on the main zone search data form, thereby eliminating the need for an additional form and making the data recording more efficient. Also, what units should be used when recording barometric pressure?
8. This SOP contains a rather long equipment list relative to others, yet several of these items are never referred to again in the SOP. For instance, it is unclear to those of us conducting the pilot study what the eyedropper and forceps are meant to be used for. Also, though it can be inferred that the 2 oz. bottle filled halfway with ethanol is meant for collecting voucher specimens, the SOP provides no mention of collecting or guidance as to when collecting is appropriate and what to do with specimens after they are collected.

Discussion

Units of Measurement

A point of general application is the choice of measurement units to be used when collecting data. The SOPs usually list values in metric units, though the instructions do not always explicitly state that data should be measured using the metric system. During the pilot study, data were inconsistently collected using both the metric system and English units. As users of these SOPs may be accustomed to using various measurement systems, it would be beneficial to provide a reminder in each SOP to always collect data in metric units. This will promote awareness of differing measurement systems, prompt users to configure instrumentation to collect data in the proper units, and prevent the need to make unit conversions during the data management process.

Ice and Water Monitoring

The primary discussion regarding this SOP during the pilot study centered on the proposal to separate this into two SOPs, one for ice and one for water. Currently, there is little mention of water level monitoring in the SOP and no data form that could be used for monitoring seasonal pools at ORCA. The information on ice monitoring does not apply at ORCA, and similarly, any information that might be included in this SOP on pool monitoring would not be relevant at LABE. Considering this, it would seem appropriate to create two separate SOPs, as the methods for monitoring ice are very different from the methods for monitoring pools, and the data being collected are also different, thus requiring two separate data forms. Including ice and water in a single SOP was initially done because both are considered part of cave hydrology, but treating both parameters in the same document makes the SOP more difficult to navigate and therefore less user-friendly.

Climate Monitoring and Use of Dataloggers

The following discussion points need to be considered in the continued development of SOP #1:

1. *Multiple entrances:* Most of the caves at LABE contain multiple entrances. This necessitates the decision of picking one entrance (from as many as five or six in some caves) to serve as the entrance for placing the logger. This decision certainly affects the data that will be collected, as attributes such as slope, aspect, elevation, size, and vegetative cover may influence the temperature and relative humidity within the entrance. In the pilot study, the upflow entrances of both Caldwell and Wishbone Caves were chosen, though this was largely by coincidence.

2. *Middle vs. deep zones:* This issue is inherently related to the fact that most LABE caves contain multiple entrances. In many of these caves, it is extremely difficult and often somewhat arbitrary to distinguish middle and deep zones. In some cases, the situation of multiple entrances and skylights can make for a cave that is essentially one large twilight zone. In this case, there clearly is no deep zone and even the presence of a middle zone may be questionable. For these types of caves, it does not seem necessary to install both middle and deep loggers.

There are two types of caves in LABE that do truly have deep cave zones. Caves of considerable length may contain areas that are significantly isolated based on distance from an entrance, supporting the idea of a deep cave zone, though this definition would require setting some minimum distance from an entrance. The other type of cave that contains a deep zone is the multi-level cave. Several caves in the Monument possess multi-level morphology that creates a distinct basement level of the cave system, usually characterized by cooler temperatures and occasionally the presence of ice.

3. *Surface loggers:* Placing a logger on the surface leaves it exposed to the effects of precipitation, wind, solar radiation, and other meteorological effects. We should examine the possibility of creating elevated housings to hold the loggers and control for these effects. Thus the logger would rest within a shaded structure and be protected from wind and precipitation. During the pilot study, surface loggers were suspended within trees, leading to the possibility that certain types of trees may have microclimates that could affect the climate data recorded by the logger.

   Also, is it necessary to place a surface logger at every cave monitoring location, or could we instead implement a number of "weather stations" that correspond to regions within the Monument? Using fewer surface loggers would be preferable, in an attempt to mitigate potential visual disturbance resulting from construction of datalogger housings at cave entrances.

   To determine what kind of variation might be expected between surface loggers that are relatively close together, loggers were placed near three cave entrances in the Balcony-Boulevard cave area. The data from these loggers was also compared to additional surface data from the Caldwell Cave and Wishbone Cave surface loggers and a logger associated with the Monument headquarters weather station.

   The following table summarizes the averages of temperature and relative humidity data points recorded at these six locations in the Monument. These data may help resolve whether there is a need for surface loggers at all caves. The averages were calculated from 309 data points spanning nearly 13 days from February 12 – 25. The headquarters logger is situated within an enclosed, elevated structure. The remaining loggers were suspended in juniper trees, with the exception of the Himmel Cave logger, which was suspended in a mountain mahogany shrub.

	Caldwell Cave	Wishbone Cave	Shark's Mouth Cave	Boulevard Cave	Himmel Cave	Head-quarters
Temp (°F)	35.70	35.51	35.60	35.67	34.33	35.50
RH	70.46	71.78	70.68	71.76	74.53	69.75

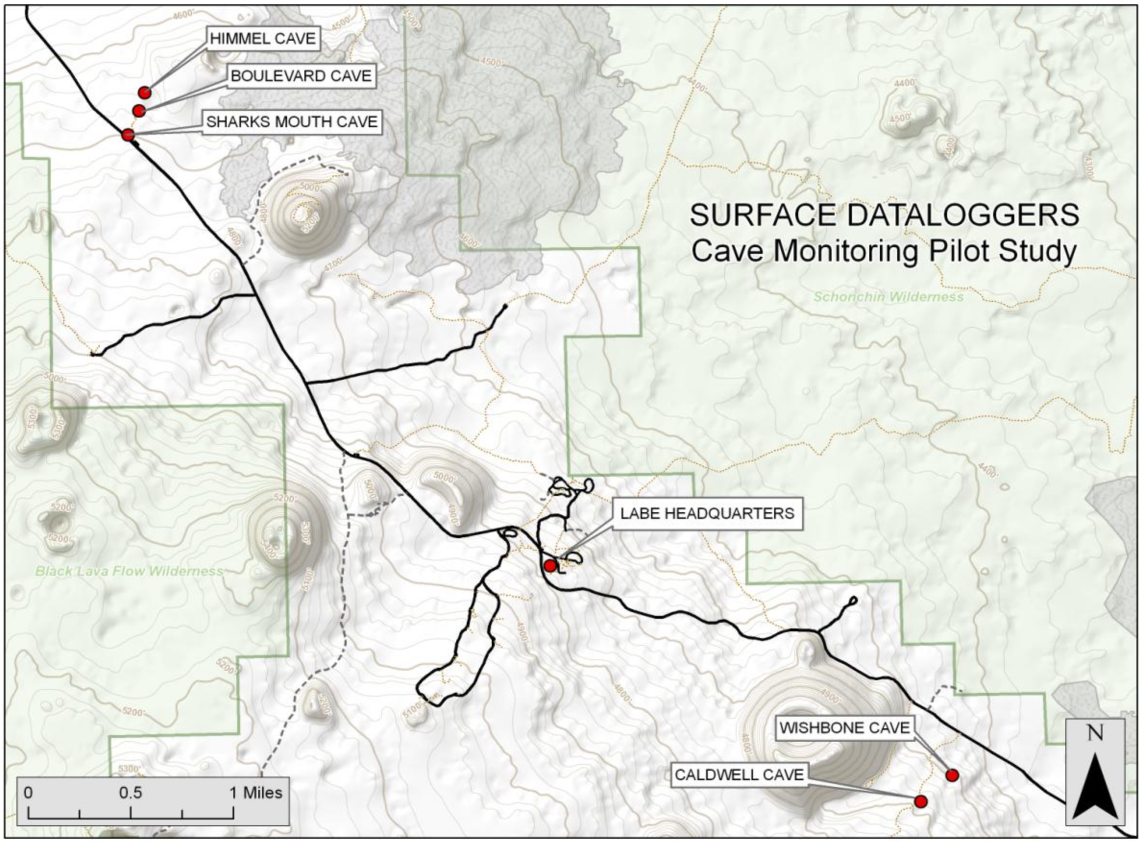

Figure 10. Location of LABE surface dataloggers placed during pilot study.

4. *In-cave placement of loggers:* At LABE, the question arose of whether the way a logger is placed in the cave could affect the data. Traditionally, there has been no one way in which loggers have been placed and positioned in caves. Oftentimes, they are simply set on a shelf or boulder, such that they are resting directly on the cave surface. In other cases, loggers have been hung with wire and suspended in air. The question was whether the rock itself, due to its specific heat or other properties, might influence the data collected relative to a logger only exposed to air. To determine the answer, three loggers were placed within 1 meter of each other in Indian Well Cave. One logger was suspended in air, another was set on a shelf, and the third was buried within several loose rocks. The loggers were left in the cave for almost 13 full days from January 28 – February 10 and set with a logging interval of 1 hour; 309 events were recorded by each logger during this time period. The averages of the datasets are as follows:

	Suspended logger	Logger on shelf	Buried logger
Temp (°F)	32.83	32.76	32.85
RH	90.88	91.52	90.01

Based on the appearance of these averages, the datasets for each logger seem to have a high degree of correlation. If these values are assumed to be within a reasonable range of each other, then it would follow that loggers may be positioned in whatever manner is most convenient at a particular cave location.

5. *CO_2 Monitoring:* Additional consideration needs to be given to CO_2 monitoring methods. The instrument recommended in the SOP is cost prohibitive, as several units would need to be purchased to conduct monitoring at multiple sites. ORCA currently uses a mobile instrument that is used monthly to collect CO_2 data at a number of sites throughout Oregon Cave. If this method is adopted for this monitoring program, the SOP will need to be updated to incorporate procedures specific to that instrument. Also, further discussion is needed to determine whether any CO_2 monitoring will occur at LABE.

Monitoring Parameters and Methods Considered but Rejected

SOP 3: Dust and Lint Monitoring

Resource managers at LABE and ORCA unanimously agree that currently available methods for monitoring of dust and lint (DL) accumulation are not practical for long-term monitoring. While it would be valuable to understand the rates of DL accumulation in caves, we do not want to pursue this type of monitoring until we have higher confidence that the methodology will produce a strong dataset. Lack of confidence in this SOP is attributed to the following:

1. Method I in the SOP requires the use of photography and measurement of DL. Photographic methods are problematic due to the difficulty in controlling photo conditions over years of implementation, as slight changes in camera quality or flash intensity can impair the ability to make photo comparisons. Additionally, the lack of quantitative data from a photographic method will complicate analysis. The measurement of DL by weight and volume are not practical, largely due to the extremely slow accumulation rates that are likely to be encountered. Also, in wet or humid conditions, the weight of a sample will be significantly heavier than a similar sample from dry conditions. Similarly, the volume of a sample will be affected by moisture, as lint will become compressed when wet and occupy far less volume than a dry sample.
2. Method II in the SOP was thrown out due to cost considerations, as the opacity meters are very expensive. This method was more promising in its ability to capture quantitative data, though the slow accumulation rates may have been difficult to capture without a controlled environment where disturbance could be avoided.
3. An alternative method was discussed at the meeting in Ashland on December 1, 2009. This method involved developing a set of 10 reference photos in which dishes would display a progression of increasing amounts of lint, ranging from a clean dish to a dish with heavy DL accumulation. This sounded like a reasonable and easy method at the time, but further consideration has led to questioning its validity. It is now believed that the development of the reference photos would be too ambiguous and prone to human bias as to what constitutes an expected range of DL accumulation. It is highly unlikely that DL accumulation in a cave would closely resemble what might be created in a set of reference photos using an available lint source, such as lint from a dryer filter. The only valid method for creating reference photos would be to show what real DL accumulation

in an actual cave environment looks like, and this is not practical as it would require years of waiting. Also, the data that would be captured from this method would likely consist only of low numbers, probably 1s and 2s, that represent the relatively clean side of the scale. This leads to the questions of whether we are learning anything from this data and whether they would have any application to management decisions.

4. Another consideration with the monitoring of DL is whether we can reasonably expect that dishes will remain undisturbed for years at a time, an assumption which is required when committing to this method. When looking at the two areas where this SOP would be implemented, this assumption loses its integrity.
    a. At ORCA, Oregon Cave and Blind Leads Cave will be monitored. In both caves, dishes would be susceptible to disturbance by visitors. Although most dishes in Oregon Cave would probably be out of reach of visitors, at least some dishes would need to be placed near the trail. Also, in several sections along the tour route, there are few if any spots that are out of reach. Blind Leads Cave is a small cave along a nature trail that receives moderate visitation and the small passage sizes lead to a high probability that any dishes placed in this cave would likely be disturbed and perhaps even broken.
    b. At LABE, there is a strong distinction between visitor use caves and backcountry caves, both of which would be part of the monitoring efforts. Visitor use caves are entered by visitors without guides, and many of these caves have been heavily impacted by visitors as evidenced by the amount of trash and lint left in the caves. The absence of trails through many LABE caves creates the effect of visitors wandering and crawling through all sections of caves. With this type of visitation, it would be impossible to prevent DL monitoring transects from being disturbed in visitor use caves. In backcountry caves that receive little to no visitation, the DL monitoring would probably work, but without being able to compare DL accumulation in backcountry caves to that in visitor use caves, the monitoring would be of little value.
5. Finding spots for DL monitoring transects would also be very difficult in some caves due to the absence of dry areas. If dishes are impacted by dripping water, the data from the monitoring would be invalidated at that location. In Oregon Cave in particular, there are very few spots that are not affected by dripping water during the winter season, so this could be a significant obstacle in finding enough transects and locations for a robust monitoring effort. Some LABE caves would also be problematic for the same reason.
6. What are we learning from this monitoring, and how will it affect our management decisions? It has long been known in the cave management community that dust and lint accumulation is an unavoidable effect of visitation. This has been demonstrated at show caves throughout the entire world. Short-term studies have been conducted at NPS cave parks and have shown a correlation between visitation and DL accumulation. With that in mind, what is the value of conducting DL monitoring as part of a long-term monitoring plan? Do we expect to obtain data that will help us learn anything we do not already know? Will the data in any way influence management decisions? These may difficult questions to answer without the benefit of a long-term dataset to analyze, but we need to justify the reasons for initiating a monitoring plan of this scale and level of effort.

SOP 6: Bat Surveys (Summer Monitoring)

Monitoring of Townsend's Big-eared bat populations cannot effectively be accomplished through outflight counts of summer maternity colonies. Instead, winter hibernacula counts will be conducted as the sole monitoring method of bat populations. Though there is value in monitoring summer colonies, the methods for monitoring population sizes and the resulting datasets are not reliable enough for consideration in this SOP. Summer bat use in Oregon Cave is generally characterized by a few solitary bats being seen throughout the summer season, so summer outfight counts would not be very practical at ORCA. At LABE, there has been a long history of conducting summer monitoring of *Corynorhinus townsendii* maternity colonies. The following points summarize the history of conducting summer outflight counts at LABE and the reasons for dismissing this method from the monitoring protocol:

1. Summer monitoring of maternity colonies of *Corynorhinus townsendii* has been of value in demonstrating recurring use of specific roost sites. This information has been used in formulating bat management strategies, including closure and active protection of several known maternity sites.
2. Summer outflight counts at maternity sites have been used to acquire estimated population counts for specific caves. These population counts have traditionally assumed that separate colonies exist in specific areas within the Monument and that individual bats remain with their respective colonies throughout the breeding season.
3. Consideration of summer outflight count methods reveals a high margin of error for the population estimates, as Townsend's colonies are notorious for displaying behavior that causes difficulty in performing an outflight count. The bats commonly fly in and out of cave entrances for some time after emergence, and many individuals will fly only within trenches between cave entrances, both of which are factors that increase the chances of counting an individual multiple times or not counting some bats at all. This possibility suggests a high degree of error in estimating the number of bats that fly out of a cave on a particular evening.
4. Townsend's colonies continue emerging from a cave, or at least continue using a cave entrance, until well after dark. This requires the use of night vision equipment, which complicates monitoring efforts, narrows the monitoring field of view, and contributes to the uncertainty level of summer monitoring efforts.

For summer outflight counts to be considered accurate estimates of bat populations requires making several difficult assumptions, namely that there is no interchange of bats between separate colonies and that monitoring methods are capable of accurately determining population sizes. Instead, winter hibernacula monitoring can be used to effectively monitor Townsend's Big-eared bat populations. Winter monitoring efforts are prone to a lower margin of error for individual cave counts, as hibernating bats are immobile and an accurate count of all visible bats is possible for the area searched, with the exception of areas with particularly high ceilings or other attributes making for difficult visibility.

The number of caves that should be monitored every winter season depends on the amount of the population that is expected to be counted each year and the amount of effort that is delegated to finding potential new hibernacula sites. Furthermore, the possible time expenditure may be dependent on park funding and staff availability.

1. Bat hibernacula monitoring has occurred during 12 winter seasons. The number of caves surveyed each winter has ranged from as few as 5 to as many as 45, with an average of 20 caves surveyed per season.
2. Based on data from 1998 – present, over 95% of the known bat populations counted each year are located in 11 specific caves. A subset of caves that generally yields the 6 highest counts contains about 90% of the known bat population.
3. In addition to the caves that are searched every year, a small number of supplementary caves could be selected for inclusion in the monitoring effort. This would promote potential discovery of new hibernacula sites and diversify the database. Randomly selected caves could be searched in conjunction with geographically adjacent caves to maximize efficiency of travel efforts.

SOP 8: Karst Invertebrate Surveys (Area Searches)

Following recent decisions among park and Network staff, monitoring of cave invertebrates will be done through the use of bait stations and area searches will be dropped from the protocol. This decision was made because available staffing can only accommodate one monitoring method, as opposed to both bait stations and area searches. Bait stations were selected as the desired monitoring method because this method will generate higher detection rates, whereas area searches will likely be less successful in detecting invertebrates and lead to datasets populated largely with zeros.

Sample Size for Cave Monitoring at Lava Beds

How many caves can be monitored at LABE? The number of caves that can be or should be monitored at LABE has been a point of discussion since the inception of this monitoring protocol. This section details the potential number of caves that can be monitored based on time commitments required by each SOP and the amount of staffing available. This sample size analysis is being done for Lava Beds but not for Oregon Caves because of the following factors:

1. The monitoring sites at ORCA have for the most part already been determined, with monitoring occurring at multiple sites in two caves.
2. Travel times to ORCA sites are insignificant relative to travel times at LABE, so the time required for monitoring at ORCA is substantially less than that required for monitoring at LABE.
3. The sample size at LABE will be dependent on the amount of available staffing and the time required to implement each SOP, whereas the sample size at ORCA has been determined by evenly distributing sites throughout Oregon Cave and adding sites at Blind Leads Cave.

During the field work phase of the pilot study, travel times to caves were recorded and used to calculate average round-trip travel times. Additionally, average preparation times were factored into the total time commitment for monitoring. Finally, in-cave monitoring times were recorded and used to calculate average monitoring times for each SOP.

Note: For the sake of the discussion and calculations in this section, the following assumptions are made:

1. SOP #3 (Dust and Lint Accumulation) is being dropped from the monitoring effort, following concurrence to this effect among LABE and ORCA resource managers.

2. SOP #6 (Bat Surveys) will only be implemented as winter hibernacula counts, as summer outflight count methods are unreliable.

LABE resource management staff estimated that the equivalent of 0.4 FTE (FTE = full-time employee) could be allocated annually towards implementation of the cave monitoring protocol. This time expenditure translates to about 104 days of work.

Every other year, on even years, monitoring efforts will be supplemented with Klamath Network funding and additional staff. During these years, the overall workload will be greater, as all SOPs will be implemented, whereas three of the SOPs (Vegetation, Scat, Invertebrates) will not be implemented on odd years. KLMN staff estimated that about $50,000 would be available on even years for cave monitoring. This amount should be sufficient to fund the equivalent of at least 0.8 FTE split between a GS-5 seasonal and a GS-7 term or permanent, which translates to about 208 days of work.

Due to the training needs involved with preparing seasonal employees to implement monitoring protocols, permanent or term LABE staff would be required to invest considerable time towards Network monitoring activities. For this reason, it would be preferable for Network funding to contribute to the salary of the GS-7 term position at LABE in addition to funding seasonal hires. Furthermore, divulging sensitive cave locations and resources to seasonal staff should be minimized, thus funding should be prioritized for long-term LABE employees rather than relying primarily on seasonal hires.

The following table summarizes projected staff costs for hiring one GS-5 seasonal employee for 6 months and funding 4 months' salary for one GS-7 term or permanent employee during the years in which Network monitoring activities are implemented:

	GS-5 pay period (PP) base rate	GS-5 6-month season cost	GS-7 term/permanent PP base rate	GS-7 4 month salary cost	Total biennial cost GS-5 + GS-7
2012	$1,288.54	$15,462.48	$1,717.57	$13,740.56	$29,203.04
2014	$1,367.02	$16,404.24	$1,822.17	$14,577.36	$30,981.60
2016	$1,450.27	$17,403.24	$1,933.14	$15,465.12	$32,868.36
2018	$1,538.59	$18,463.08	$2,050.87	$16,406.96	$34,870.04

The costs listed in the table above should leave a substantial portion of funding available for equipment, travel, and other expenses.

Odd Years

During odd years, annual monitoring will be implemented by LABE staff. Biennial monitoring conducted by Network staff will not occur during odd years.

LABE monitoring responsibilities: SOP #1: Climate, SOP #2: Ice, SOP #4: Visitation, SOP #6: Bats

KLMN monitoring responsibilities: Network monitoring does not occur on odd years.

Available staffing: 0.4 FTE (LABE) = 104 days

Implementation schedule:

Winter	Ice and Bats (plus Climate and Visitation in Ice caves and Bat caves)
Spring	Climate and Visitation, as needed
Summer	Ice; Climate and Visitation, as needed
Fall	Climate and Visitation, as needed

Time expenditure for LABE: The following time estimates take into consideration all aspects of the monitoring process, including preparation time (e.g., organizing gear, printing maps and data forms), travel time, actual field work, and data management.

<u>SOP #1: Climate Monitoring</u>
When the Climate SOP is being implemented alone, the primary time expenditure will be travel to and from caves, as the actual offloading of data from loggers will proceed quickly. On average, it should be reasonable for two employees to visit four caves in 1 day when implementing this SOP. Thus, one cave visit requires 0.5 staff days. As caves need to be visited three times per year to download loggers, one cave would require 1.5 total staff days annually.

3 visits × 2 staff × 0.25 days/visit = 1.5 staff days per cave

<u>SOP #2: Ice Levels</u>
Ice monitoring is currently being conducted at a total of nine sites in seven caves, and this SOP calls for ice surveys to occur twice per year. To implement this SOP as proposed with the new methods, it would be possible for two employees to survey two sites in 1 day. An extra day will be required for data processing each season. Thus, implementation of this SOP would require a total of 10 staff days during each monitoring season, or 20 total staff days per year.

2 visits × 2 staff × 0.5 days/visit = 2.0 staff days per site
(2 staff days/site × 9 sites) + 2 data processing days = 20 staff days per year

<u>SOP #4: Visitation Monitoring</u>
Visitation monitoring is accomplished by two different methods, infrared trail counters and cave registers, both of which require approximately the same level of effort but require different sampling intervals. Implementation of this SOP in backcountry caves can be done concurrently with Climate monitoring, which will occur three times per year. For frontcountry caves that receive higher visitation, infrared trail counters, downloaded monthly, will be used. Caves with infrared counters will be those that are relatively close to roads and trailheads, so it will be possible to download all the counters in 1 day by a single employee. An extra half-day will be required for data processing each month. Therefore, implementation of this SOP will require 18 total staff days per year.

1 day/month (field work) + 0.5 day/month (data processing) = 18 staff days per year

<u>SOP #6: Bat Surveys</u>
Winter hibernacula counts need to be conducted annually in a specific set of at least six caves to ensure that the majority (>90%) of the known *Corynorhinus townsendii* population is counted. Conducting annual counts in 20 caves will allow for a sampling design that accommodates

searching new caves each year with the possibility of discovering previously unknown hibernacula sites. Many of the known hibernacula sites are relatively remote, so travel times are a significant factor in the total time expenditure for implementing this SOP. On average, two employees can survey two caves in 1 day, with enough remaining time for all data processing. Therefore, performing hibernacula counts in 20 caves each winter will require 20 total staff days.

1 visit × 2 staff × 0.5 days/visit = 1 staff day per cave
1 staff day/cave × 20 caves = 20 staff days per year

LABE totals

Time expenditures can be calculated for Ice, Visitation, and Bats, as these parameters are being monitored in a known set of caves and current practices and pilot study results allow estimation of the required effort. SOP #1 (Climate Monitoring) will be implemented in an as yet unknown number of caves, so the total time expenditure cannot be calculated. Rather, the amount of available staffing remaining after considering workloads required by the other SOPs can be used to determine the number of caves that can be selected for implementation of climate monitoring.

104 days	LABE available staffing
– 20 days	SOP 2 (Ice)
– 18 days	SOP 4 (Visitation)
– 20 days	SOP 6 (Bats)
= 46 days	LABE remaining staffing

After considering the workloads required by the other SOPs, 46 days of available LABE staffing remain. Given that two employees will be used to implement the Climate SOP, there are effectively 23 field days that can be utilized. As four caves can be monitored in 1 day, it would be possible to make 92 cave visits per year. Since each monitored cave consumes three cave visits per year, it follows that about 30 caves could potentially be selected for implementation of climate monitoring.

46 staff days ÷ 1.5 staff days/cave = 30.67 caves
or
46 staff days ÷ 2 staff = 23 field days
23 field days × 4 caves/day = 92 cave visits
92 cave visits ÷ 3 visits/cave = 30.67 caves

This cave estimate is quite conservative, as it will only be absolutely necessary for two employees to be present when backcountry caves are being visited. Offloading data from loggers in frontcountry caves can be safely conducted by a single employee.

Even Years

During even years, normal annual monitoring will continue at LABE and ORCA. The following section deals exclusively with biennial KLMN monitoring activities.

KLMN monitoring responsibilities: SOP #5: Fern, Moss, and Lichen (FML), SOP 7#: Scat, SOP #8: Invertebrates

Available staffing: 0.8 FTE (KLMN) = 208 days

Implementation schedule:

Winter	no KLMN monitoring activities
Spring	no KLMN monitoring activities
Summer	FML, Scat, Invertebrates
Fall	no KLMN monitoring activities

Time expenditure for KLMN: The following time estimates take into consideration all aspects of the monitoring process, including preparation time (organizing gear, printing maps and data forms), travel time, actual field work, and data management.

<u>SOP #5: Fern, Moss, Lichen Monitoring</u>
Methods for monitoring of fern, moss, and lichen coverage at cave entrances have yet to be determined, though recent discussion has centered on conducting point surveys along transects. With such a method, it would be reasonable to expect that two caves could be monitored in one day using two employees. Therefore, monitoring of one cave would consume a total of 1 staff day.

1 visit × 2 staff × 0.5 days/visit = 1.0 staff days per cave

<u>SOP #7: Scat Monitoring</u>
Scat monitoring will be conducted in conjunction with invertebrate monitoring, so the time expenditure for both SOPs will be treated together under the invertebrate heading.

<u>SOP #8: Cave Invertebrate Monitoring</u>
The time expenditure calculated for monitoring cave invertebrates is based on using bait stations, which requires two visits to each cave. During the pilot study, only area searches were conducted; however, the amount of time required for monitoring bait stations will be roughly the same per visit, especially considering that travel times to and from the caves will constitute the majority of time required. Conducting scat monitoring and invertebrate monitoring simultaneously will allow two employees to monitor two caves in 1 day, and all caves will need to be visited twice. Therefore, monitoring of one cave would consume a total of 2 staff days.

2 visits × 2 staff × 0.5 days/visit = 2.0 staff days per cave

<u>KLMN totals</u>

Fern, Moss, and Lichen Monitoring	1.0 staff days per cave
Scat + Invertebrate Monitoring	2.0 staff days per cave
Total time expenditure	*3.0 staff days per cave*

The total time expenditure per cave for KLMN monitoring is probably quite conservative, as it does not take into consideration that FML monitoring could potentially be implemented in conjunction with scat and invertebrate monitoring, thus reducing overall travel times.

The estimated 208 available staff days would need to be split between field activities at LABE and ORCA, data management, data analysis, report development, travel, and likely other incidental duties. If 60% of the staff days are used for field work, which assumes that field work would be conducted on average 3 days per week, then 125 staff days would be available for implementation of the monitoring SOPs.

The 125 field days would need to be split between LABE and ORCA. Assuming that LABE field work would constitute about 70% of the total effort, based on the significantly greater travel distance and the greater number of sites, about 88 field days would be allocated at LABE.

With an average total time expenditure of 3.0 staff days per cave for KLMN monitoring on even years, it would be possible to monitor nearly 30 caves at LABE.

> 208 staff days × 60% field work = 125 staff field days
> 125 staff field days × 70% LABE allocation = 88 LABE staff field days
> 88 LABE staff field days ÷ 3.0 staff days per cave = 29.3 caves

Conclusion

During odd years, LABE staff will be capable of monitoring at least 30 caves when implementing Climate, Ice, Visitation, and Bat SOPs.

During even years, KLMN funding will be sufficient to allow monitoring of at least 29 caves when implementing FML, Scat, and Invertebrate SOPs.

The time estimates used to calculate the potential sample sizes were very conservative, so monitoring roughly 30 caves at LABE should be reasonable.

Literature Cited

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